Engineering Report

NuTech Orchard Removal, LLC

vs.

DuraTech Industries International, Inc.

Case No.: 3:18-cv-00256-DLH-ARS
United States District Court
District of North Dakota
Eastern Division

Prepared by:
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February 28, 2020
8553

EXHIBIT 2

3:18-CV-256

Forensic Engineering Technologies

ASSIGNMENT

Forensic Engineering Technologies, LLC (FET) was retained on January 23, 2020 by Attorney Justin Eichmann of Houghton Bradford Whitted PC, LLO to evaluate the condition, design, and operation of a DuraTech 5064T horizontal grinder.

The scope of work includes machine inspection, reports prepared by others, pleadings, complaints, research, analysis, and report preparation. FET performed the work in this matter using the care and skill ordinarily used by members of the of the subject profession practicing under similar circumstances at the same time and locality.

INVESTIGATION

During our analysis, we reviewed, analyzed, and considered the following items and material:

1. Pleadings
    a. Plaintiff's Complaint and Demand for Trial by Jury filed December 6, 2018
    b. Defendant's Answer, Affirmative Defenses and Jury Demand filed February 6, 2019
2. Discovery Responses
    a. Plaintiff's Initial Disclosures dated March 29, 2019 and documents Bates-stamped Nutech 0001-44
    b. Defendant's Initial Disclosures dated March 29, 2019 and documents Bates-stamped DTI00001-39
    c. Defendant's Answers to Interrogatories & Responses to Requests for Production dated May 24, 2019 and documents Bates-stamped DTI00040-414
    d. Plaintiff's Answers to Interrogatories & Responses to Requests for Production dated May 30, 2019 and documents Bates-stamped Nutech 0045-160
    e. Defendant's Supplemental Response to Request for Production dated June 20, 2019 and documents Bates-stamped DTI00415-605
    f. Defendant's Second Supplemental Response to Request for Production dated August 9, 2019 and documents Bates-stamped DTI00606-1618

g. Defendant's Answers to Interrogatories (Second Set) dated September 30, 2019 and documents Bates-stamped DTI01619-1622
h. Plaintiff's Answers to Interrogatories & Responses to Requests for Production (Second Set) dated October 4, 2019 and documents Bates-stamped Nutech 0161-244
i. Documents Bates-stamped DTI01623-1639 produced November 6, 2019
j. Plaintiff's Supplemental Responses to Requests for Production dated November 19, 2019 and documents Bates-stamped Nutech 0118-128 (unredacted) and Nutech 0245-257

3. Subpoena Responses

   a. Subpoena Response of Charles A. Hayes d/b/a CH Balancing dated August 1, 2019
   b. Subpoena Response of Holt of California dated August 8, 2019
   c. Subpoena Response of Quinn Company d/b/a Quinn Power Systems dated October 14, 2019
   d. Subpoena Response of Red Barn Equipment Sales, Inc. dated October 22, 2019

4. Depositions

   a. Deposition of Bob Strahm dated August 26, 2019
   b. Deposition of Mike Bartle dated August 26, 2019
   c. Deposition of Jay Grotrian dated August 27, 2019
   d. Deposition of Tim Wehling dated August 27, 2019
   e. Deposition of Dexter Long dated October 28, 2019
   f. Deposition of Richard Miller dated October 28, 2019
   g. Deposition of Omar Huerta dated October 29, 2019
   h. Deposition of Eric Hueval dated October 29, 2019
   i. Deposition of Javier Garcia dated October 29, 2019
   j. Deposition of Catarino Cortex dated October 29, 2019
   k. Deposition of Dan DeJong dated October 29, 2019
   l. Deposition of Nathan DeJong dated October 30, 2019
   m. Deposition of John Vanderhelm dated October 30, 2019
   n. Deposition of David H. Long dated October 30, 2019

5. Plaintiff's Expert Witness Disclosure
    a. Plaintiff's Expert Witness Disclosure dated December 2, 2019 and Exhibits A, B and C thereto

Material Review

In August 2017, NuTech purchased a 5064T Horizontal Grinder from DuraTech to grind almond trees. Machine components include a diesel engine, electronic engine controls, feed floor, PLC, rotor and hammer assemblies, feed wheel, and belly and discharge conveyor assemblies. NuTech modified the original configuration of the 5064T horizontal grinder by removing the discharge-conveyor assembly and attaching spreaders to the discharge chute.

NuTech operated the 5064T grinder for approximately 1,760 hours. The 5064T horizontal grinder grinds wood waste, green waste, construction and demolition debris, and tree branches and trunks. The machine operated for approximately 800 hours before the rotor bearings were first replaced. Subsequent rotor-bearing replacements became more frequent occurring at an average interval of approximately 280 hours. Structural cracks at welded connections developed and vibrational issues were not satisfactorily resolved.

FET inspected subject and exemplar DuraTech 5064 horizontal grinders on February 14, 2020.

Review and consideration of the current materials reveal the following facts about the 5064T horizontal grinder:

- The 5064T grinder was placed into service with NuTech on October 9, 2017.
- The 5064T horizontal grinder was not anticipated to be a consumable product. Except for wear-out components such as hydraulic and engine oil, hammer tips, screens, or filters, the grinder doesn't have a definitive wear-out life. With proper operation, care, and maintenance, the endurance of the 5064T can exceed 1,760 operational hours.
- Typically, Weibull analysis and reliability engineering methods are used to understand factors causing system failure and component wear-out so downtime can be minimized. As a result of these techniques, approximately 90 percent of machine failures are not due to a wear-out failure condition. The probability that

the wear-out failure of the 5064T signifies equipment misuse involving operator error and/or lack of maintenance is high.

- The cause of rotor vibration is currently unknown.
- Duratech's design process relies on their experience and collective knowledge. Design is an aggregate effort where products are produced using feedback from sales personnel and the cumulative experience gained from building prior machine models.
- The rotor bearings in the 5064T grinder are manufactured by Dodge and have designated part numbers P4B526-ISAF-407L (pulley side) and P4B526-ISAF-407LE (non-pulley side). The original bearings and subsequent replacement bearings matched specifications and were installed in their proper locations.
- The type of seal used in the bearings is a labyrinth design. These seals feature rigid shields mounted to the inner and outer (rotating and fixed) components of the bearing assembly. There are two small gaps: between the fixed shield and rotating inner ring of the bearing, and between the fixed and rotating shields. The gaps form a pathway from the bearing's exterior to interior surfaces. Grease filling the labyrinth lubricates the roller bearing and forestalls entry of external contaminants. As new grease is pumped into the bearing during regular service intervals, the new grease expels gritty unclean grease along with external contaminants from the labyrinth to keep the bearing lubricated and uncontaminated.
- The originally installed bearings faultlessly operated for over 800 hours. The first bearing replacement, on the pulley side of the grinder, was performed with approximately 815 hours on the grinder. The second original equipment bearing, on the non-pulley side of the grinder, was replaced on January 26, 2018 with 849 hours on the grinder.
- Thereafter, replacement bearings began failing at much shorter intervals: 235, 269, and 334 hours respectively for the non-pulley-side bearing (Figure 1). The life of a bearing averaged approximately 280 hours or about one-third the life of the original part. The pulley-side bearing was replaced at or near the same time that the non-pulley-side bearing was replaced.

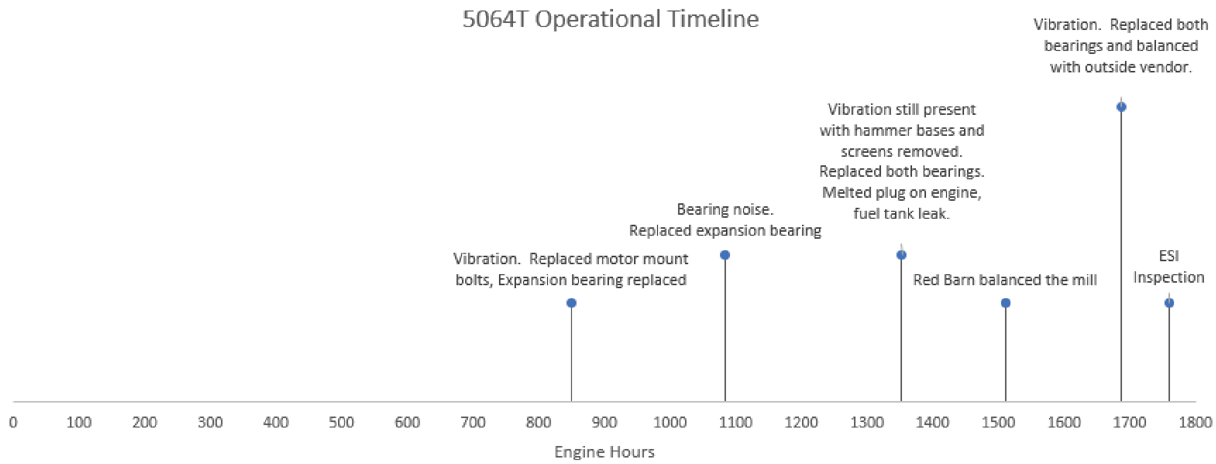


Figure 1: Timeline showing operational repairs versus engine hours.

- The bearing manufacturer (ABB — Dodge Bearings and Power Transmission) analyzed the original bearings and the first replacement set of bearings. Their analysis found that the original bearings were insufficiently lubricated and that the lubricant in the first set of replacement bearings was contaminated ("gritty"). Additionally, based on the condition of bearing components, the manufacturer noted insufficient lubrication, dynamic misalignment, and excessive vibration as probable factors contributing to bearing failure for all four bearings.
- Reports of excessive vibration began with the first expansion-bearing replacement at 849 hours. The hammer mill was rebalanced at 1510 hours by Red Barn and rebalanced again at 1687 hours by CH Balancing. Vibrational complaints were reported during each bearing-replacement service. Vibrations continued through service by CH Balancing at 1687 hours and persisted thereafter. The 5064T was transported to Red Barn 70 operational hours later with 1759 hours showing on the machine.
- No party can confirm that proper rotor-balancing means and methods were used. No party has knowledge that the 5064T grinder was idle long enough to balance the hammer mill, disassemble the hammer mill, or determine factors causing rotor imbalance.
- Given the frequency of the bearing replacement compared to the service life of the original, under-lubricated parts, the onset of the vibration likely happened sometime between 600 and 800 hours of operation.

- Software continuously monitors the rotational speed of the hammer mill/rotor (rotor speed). Grinding efficiency and throughput relies on maintaining a somewhat constant rotor speed. When the rotor speed falls below a setpoint, the direction of the feed floor and roller reverses then stops in order to remove the load on the rotor and allow it to regain the desired rotor speed. Once the rotor speed is satisfactory, the feed floor and roller restart and grinding resumes. Videos show occurrences when the operator of the excavator pushed trees toward the rotor. Pushing material into the machine potentially allows material to interact with an under-speed rotor when the machine would otherwise be unloading the mill. The effects of such a condition on the rotor or grinder are unknown.
- NuTech operators pushed trees into the grinder's intake, overrode the feed system, and caused the feed roller to stop.[1]

Subject 5064T Grinder Conditions and Observations

John Thomazin, P.E. and Chip O'Toole inspected the subject 5064T horizontal grinder on February 14, 2020. The grinder was parked unsheltered outdoors at Hilltop Ranch, approximately a mile south of 1380 Looney Road, and was inspected there as is (Figure 2). Hydraulic oil was leaking from the oil reservoir, tape had been applied to the fuel tank to prevent water ingress into the fuel, and corrosion was present on unpainted surfaces. The grinder's serial number is 70-2-14-0004 and is powered by a CAT 540 horsepower diesel engine stamped with a serial number of MCW06092.

[1] DuraTech videos produced June 20, 2019: DTI00593 @ 2:05, DTI00597 @ 0:22, and DTI00598 @ 3:07.

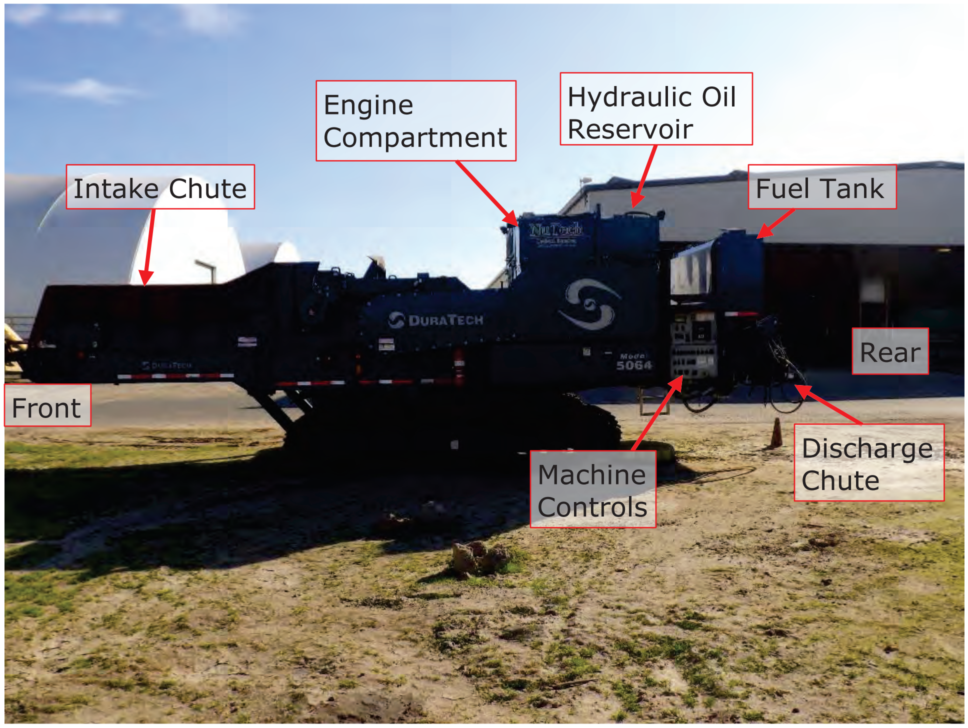


Figure 2: Photo of the 5064T grinder showing relative locations of various components on the pulley side (right) of the grinder. The rotor bearing on this side of the grinder is fixed.

The inspection progressed in three steps: exterior observations and documentation, engine startup, then rotor operation. With the rotor spinning, the engine RPM was increased from 1,000 RPM, to 1,500 RPM, then to 1,800 RPM. Vibration intensity increased as engine speed increased.

Exterior Observations

The overall condition of the grinder is poor, which is indicative of inoperable machinery needing substantial repairs and/or replacements of machine components or systems before the machine can function. Observations of the machine's exterior include the following:

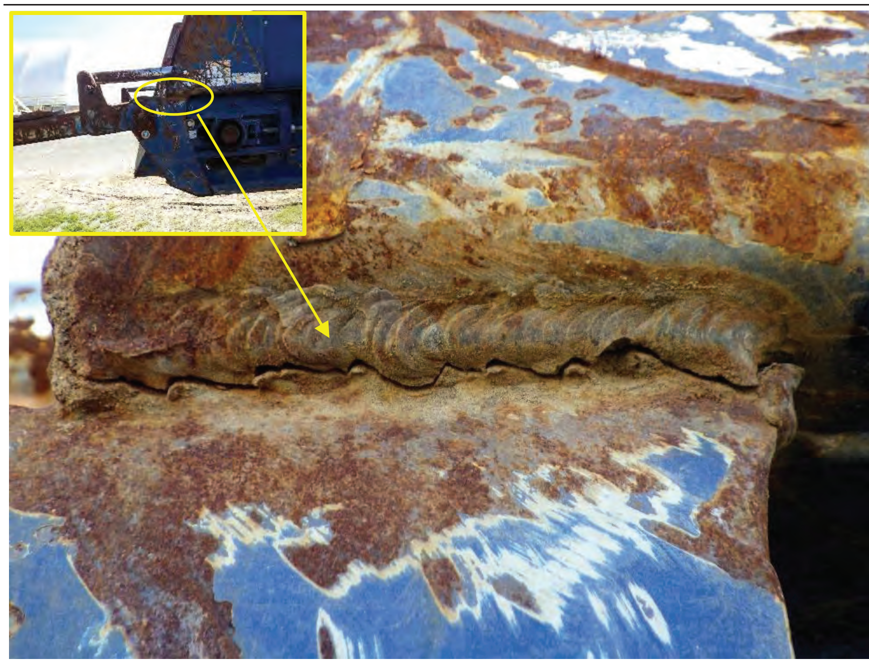
- Surface corrosion on unpainted surfaces of the grinder indicates that it had been parked outside since grinding concluded.
- Fractures in welded joints, framework, and sheet metal components.
- The sidewalls forming the intake chute are damaged. Side panels are concave rather than flat.
- Debris and dirt occupying pockets and cavities.
- Hydraulic oil is leaking from its tank.

- Rotor bearings had been greased. Grease was expelled through the seal.
- The track assembly is fastened directly to the framework of the grinder.
- The rectangular screen in the grinder was fretted.
- Rotating the rotor by hand was laborious. The rotor didn't spin easily.
- Counterbalancing weights had been removed and added to the rotor.

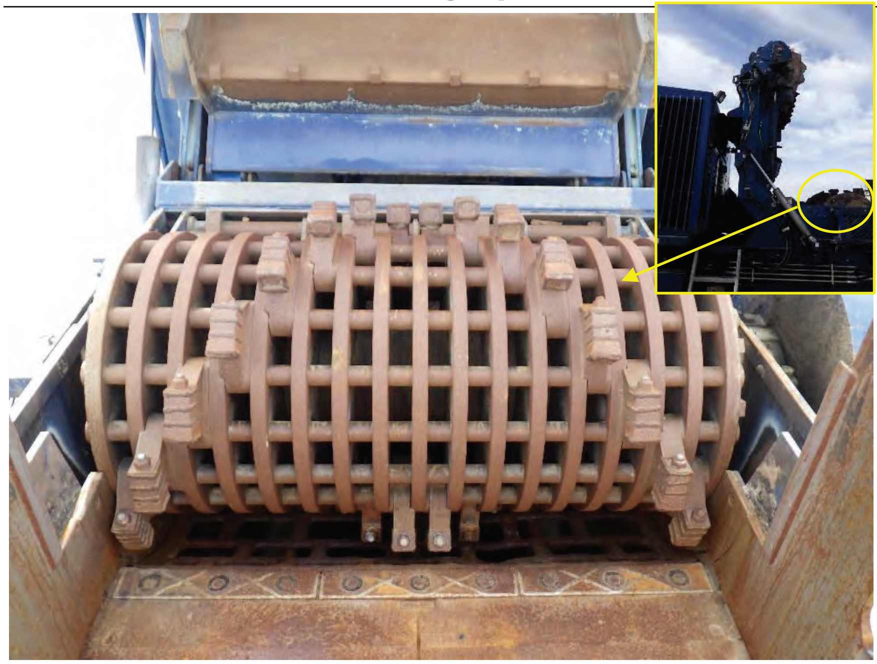
Photograph	**Description**
	Photo shows the rear (discharge) side of the grinder. The spreader has been removed from the grinder. Tape has been applied to the top of the fuel tank to prevent water ingress into the fuel tank. Vibrations have created a fracture where the horizontal and vertical sides of the sheet metal intersect. Inset shows the tape covers a welded joint.
	Photo shows the left side of the grinder. The rotor bearing on this side of the grinder allows axial movement.

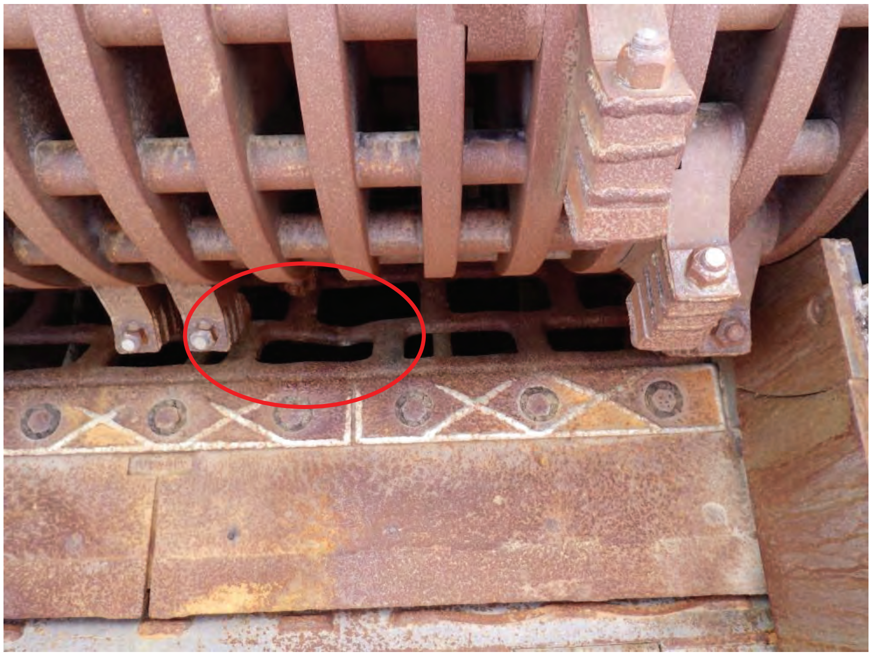
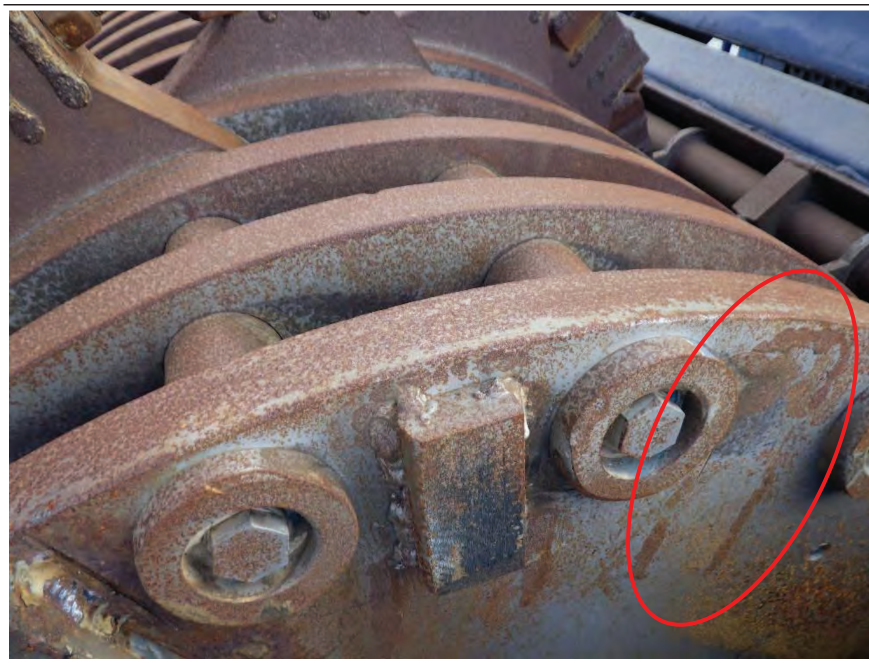
Photograph	Description
	Photo shows an oblique view of the front side of the grinder. The sheet metal forming the sides of the chute are concave, dented, and fractured indicating that multiple collisions occurred while the machine was loaded. The front table assembly is shown in the down position.
	Photo shows the intake to the grinder's feed roller and feed floor. The front table assembly is shown in the down position. Sidewalls of the chute are concave rather than flat.

Photograph	Description
	Photo shows debris and dirt accumulation in the cavity housing the cylinder connected to the front table assembly. Inset shows the relative location of the cavity and cylinder on the grinder. The condition of the cavity on the right side of the grinder resembles the photograph shown here.
	Photo shows that debris and dirt extend to the back of the cavity housing a cylinder. The feed roller and feed floor transport material to the hammer mill, and their feed rate is interlocked to the rotor’s speed. Debris here indicates that material was pushed into the hammer mill as the grinder was loaded.

Photograph	Description
	Photo shows a fracture in a bracket below the fuel tank. Inset shows the relative location of the fracture on the grinder.
	Photo shows a fracture through a welded joint connecting the front table assembly to the grinder's frame. Inset shows the relative location of the fracture on the grinder.

Photograph	Description
	Photo shows a fracture formed in the welded joint directly above the connection to the track assembly. Inset shows the relative location of the fracture on the grinder.
	Photo shows the condition of the flared side of the chute. The condition of the chute on the opposite side is similar. Chute surfaces should be flat, not concave.

Photograph	Description
	Photo shows the hammer mill/rotor. Inset shows the location of the hammer mill and feed roller in the open position.
	Photo shows grease spun around the rotor's bearing.

Photograph	Description
	Photo shows the screen is damaged.
	Photo shows counterbalance weights attached to the rotor. Red oval marks the location where a weight was removed from the rotor.

Engine Startup

The following observations were made during engine startup:

- The engine started easily.
- With the engine running and rotor idle, the grinder didn't vibrate.
- The engine's tachometer displayed 1,760 hours.

Rotor Operation

The following observations were made during rotor startup:

- The engine lugged during rotor startup.
- The entire grinder vibrated as the rotor spun at low or high speeds. Vibration intensity was greatest at high RPM. Vibration intensity was most severe as the rotor accelerated then attenuated once constant rotor speed was attained.
- At high or low engine RPM, vibrations from the grinder could be felt underfoot near the grinder.
- The speed of the feed floor RPM was set at 100 percent, and the speed of the feed roller RPM was set at 70 percent.

Exemplar 5064 Grinder Condition and Observations

An exemplar DuraTech 5064 horizontal grinder was available approximately 12 miles from Hilltop Ranch at Castle Farms in nearby Merced, California. The grinder's serial number is 70-2-10-0001 and is powered by a CAT 540 horsepower diesel engine stamped with a serial number of JRE10891.

Exterior Observations

The exemplar grinder was in good condition, which is indicative of operable machinery where repairs are done as necessary and maintenance is performed regularly. The exemplar grinder was operating before we arrived at the site. As we arrived, the operator was using compressed air to remove debris and dirt from the machine's grills, bearings, flat surfaces, cavities, ledges, and engine compartment. Photographs are a representative sampling of the machine's condition, not an exhaustive sampling. Exterior observations include the following:

- Almond trees were prepped before the grinding operation. Root balls were cut from the trees so dirt could dry and fall from the root ball before being ground. The crown was compressed to lessen the chance of tree branches snagging the chute during loading and intake.
- Unpainted surfaces of the grinder were bright indicating use.
- The sidewalls forming the intake chute are flat, undented, but marred.
- A four-inch-diameter screen was present in the grinder.
- Rotating the rotor by hand was effortless. The rotor spun easily.
- Counterbalancing weights were present on the rotor.

- The operator would spend approximately two hours maintaining the grinder after grinding concluded. He used compressed air to remove dirt and debris from the machine before greasing it.

Photograph	Description
	Photo shows the right side of the exemplar 5064 grinder. The fixed bearing is located on this side of the grinder.
	Photo shows the sidewall of the chute.

Photograph	Description
	Photo shows the hammer mill/rotor.
	Photo shows the four-inch diameter screen.

Photograph	Description
	Photo shows the feed roller locked in the up position.

Engine Startup

Observations during engine startup include the following:

- The engine started easily.
- With the engine running and rotor idle, the grinder didn't vibrate.
- The engine's tachometer displayed 2,750 hours.

Rotor Operation

Observations during rotor startup include the following:

- The engine didn't lug during rotor startup.
- No machine vibration as the rotor spun or as the rotor speed increased.
- The speed of the feed floor RPM was set at 77 percent, and the speed of the feed roller RPM was set at 78 percent.
- Almond trees were loaded trunk-first into the chute. The operator would manipulate and relocate the trees after they were placed in the chute primarily by lifting the crown, but he let the feed floor and feed roller function by letting the feed system regulate grinding throughput. The load on the engine when grinding almond trunks was higher than when grinding the crown, and the time required when grinding trunks was longer than when grinding the crown.

Discussion

Rotating machine components are common in mechanical and electromechanical systems such as engines, machining tools, electric motors, propellers, gas turbines, tires, et cetera. Rotor imbalance occurs when mass distributed around an axis of rotation (bearing axis) is uneven and results in vibrations. A mass axis is the axis around which the mass is evenly distributed. The distance between the bearing axis and mass axis is eccentricity. Balance occurs when the eccentricity between the mass axis and bearing axis is small. The unbalanced centrifugal forces, perceived as vibrations, cause bearing failure and large unbridled forces can destroy a mechanical system.

Vibrations in machinery are diminished by adding counterbalancing weights to rotating components. A balanced rotor increases bearing life, minimizes vibrations, reduces power losses, decreases noise, and prolongs machine life. Centrifugal forces caused by uneven distribution of mass around an axis of rotation are proportional to the square of the rotational speed. If the rotational speed doubles, then the force quadruples. Vibrations at low speeds may not be problematic, but vibrations at high speeds can become hazardous. Whether a rotating component has high rotational speed and low mass, such as gas turbines or jet engines, or low rotational speed and high mass, such as ship propellers or hammer mills, a balanced rotating system is essential because an unbalanced system produces vibrations and can result in failure of the entire mechanical system.

Opinions and Conclusions

Based upon review of the material referenced, information available to or obtained by me, and my experience and training as a licensed engineer, I have reached the following conclusions and opinions regarding the condition of the 5064T horizontal grinder:

1. DuraTech correctly specified the rotor bearings, and the installed bearings were fit for operation.

   Basis: Maintenance and upkeep, condition, and operation of the exemplar 5064 Horizontal Grinder. Exemplar grinder has 2,750 engine hours. Dodge Bearing Catalog: CA3000B.pdf.

2. Bearing failure and fractured machine framework is symptomatic of an unbalanced rotor effecting large vibrations. Bearings don't cause vibrations; however, vibrations damage bearings. Rotor imbalance produced vibrations which caused the damage to bearings and framework.

   Basis: Machinery dynamics.[2] ABB bearing analysis.

3. Manipulating, repositioning, or pushing trees when they're in the chute and overriding the grinder's feed system is a reasonable source of hammer mill damage causing its imbalance and cannot be eliminated as a contributing factor. Rotor damage probably occurred when the rotor speed dropped below its setpoint as trees were pushed into the hammer mill.

   Basis: DuraTech videos produced June 20, 2019: DTI00593 @ 2:05, DTI00597 @ 0:22, and DTI00598 @ 3:07.

4. Operating the 5064T horizontal grinder in its current condition is hazardous, and it is unfit for operation. Working the grinder until its current condition materialized indicates poor oversight, maintenance, and misuse. Current rotor imbalance and framework damage necessitates substantial repairs and/or replacements of machine components or systems before the machine is fit for operation.

   Basis: Visual observations and conspicuous damage to the framework, and systemwide vibrations as the rotor spins through a range of RPMs.

5. Contaminated grease within the subject bearing indicates that bearing maintenance was insufficient in terms of grease volume and/or frequency.

   Basis: ABB bearing analysis.

6. Sometime prior to the first bearing replacements around 800 hours, imbalance and vibration in the hammer mill occurred and continued thereafter. Subsequent vibrations were overlooked. The probability that the hammer mill was somehow

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[2] Faulkner, L L, and Earl Logan. *Handbook of Machinery Dynamics*. New York: Marcel Dekker, 2001. Print.

damaged or was caused to become imbalanced during operation prior to or near 800 engine hours is high.

Basis: Catarino Cortex deposition (lines 9-22, pg. 11).

7. After multiple attempts to balance the rotor, rotor imbalance persists and the source of imbalance is unknown. The 5064T grinder conspicuously vibrates when the rotor is unloaded and freely rotating.

   Basis: Current condition and operation of the 5064T grinder. Deposition of John Vanderhelm (lines 9-16, pg. 21).

FET's current evaluation of the 5064T horizonal grinder is based upon the material (listed in the section entitled Investigation) provided by Mr. Eichmann, and observations of subject and exemplar 5064 horizontal grinders. FET's opinions are based upon education, training, and experience, and the information currently available at the time of this assignment. FET assumes that any information provided by interested parties is correct and complete.

SIGNATURE

The opinions and conclusions expressed in this report are based upon a review of the material currently available to me, as well as my education, training, and experience as a licensed professional engineer, and have been reached within a reasonable degree of engineering and scientific certainty. These opinions and conclusions are based upon the information currently available to me and may be amended or supplemented should new information become available.

FORENSIC ENGINEERING TECHNOLOGIES, LLC.
John A. Thomazin, P.E.
Project Manager

Appendix A – Curriculum Vitae
Appendix B – Compensation